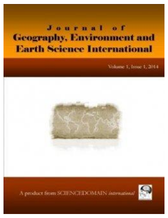

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Meteorological Variables That Affect Visibility Degradation and Their Seasonal Trends in the Niger Delta Region of Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study of visibility in the Niger Delta region is necessary because it reflects the atmospheric changes caused by economic expansion in Nigeria. Cities in the Niger Delta (especially Port Harcourt) are the most polluted cities in the country and therefore visibility degradation has become one of the major environmental challenge in Nigeria. Analysis of a 31 years (1981-2012) monthly mean horizontal visibility data and monthly mean datasets of meteorological parameters such as relative humidity and wind direction obtained from Nigerian Meteorological Agency (NIMET) and the National Centre for Environmental Prediction (NCEP) for Calabar, Uyo, Port Harcourt, Owerri, Warri and Akure was done using statistical techniques. A correlation analysis was done and the annual visibility variability indexes from (NIMET) shows significant correlation with the (NCEP) datasets for R/humidity at r=0.1334 and Wind direction at r=0.1210 respectively at 90% confidence level from t-test. This study concluded that the relationship of the atmospheric visibility and meteorological factors are closely related. The results showed that visibility is more correlated with Relative humidity in places with high hydrocarbon activities leading to excess aerosol loading like Port

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Harcourt while it is better correlated with wind direction in places with less hydrocarbon activities like Calabar and Akure. The results of this study can assist policy makers and operators in establishing positive strategies to improve the air quality.

Keywords: Meteorological; variables; visibility; degradation; seasonal trends; Niger Delta.

1. INTRODUCTION

Dramatic economic and industrial developments as well as vigorous urbanization in Nigeria have led to increased emission of pollutants from urban areas, making visibility degradation one of the severe environmental problems in such a rapidly changing country. Low visibility in Nigeria (especially in the Niger Delta region) is reported to cause 527,000 deaths due to road, air and sea accidents annually according to World Health Organization (WHO). The cities in the Niger Delta (especially Port Harcourt) are the most polluted cities in the country. Therefore visibility degradation has become one of the major environmental challenges in Nigeria, especially in the Niger Delta region that requires constant monitoring.

Studies according to [1,2,3] have evaluated long-term visibility observations and impacts of dominant air pollutants on local visibility. Also, the degree of visibility degradation in the Niger Delta Region has been found to be a function of season and region mainly due to the different concentrations of aerosols at different season and location owing to its variations of climates. The climate of Nigeria is usually characterized by two distinct seasons, namely; Summer (dry season) and Harmattan (cold-wet season), [4].

Another study by [5] recognized dust haze as the principal pollutant in Nigeria and in the Niger Delta that causes low visibility. This is due to the position of Nigeria in sub-Saharan West-Africa where dust aerosols are being transported regularly from Sahara desert. Dust aerosols are also emitted and circulated locally due to favorable weather conditions, especially in the northern part of Nigeria, even though, significant economic and population growth are obvious in Nigeria (http://www.who.africa.org (accessed on 28th March 2016). The emission and transportation of these particles are increasing annually and seasonally with increasing number of hazy days. Low visibility has been reported to have adverse effects on traffic safety, economy, human health and many more in Nigeria [6,7,8].

1.1 Study Area

Fig. 1 shows the map of Nigeria indicating the Niger Delta states. The Niger Delta area in Nigeria is situated in the Gulf of Guinea between longitude (5.05E-7.17E and latitude 4.15 N- 7.17 N). It is the largest wetland in Africa and the third largest in the world consisting of flat low lying swampy terrain that is cress crossed by meandering and anatomizing streams, rivers and creeks. It covers 20,000km^2 within wetlands of 70,000 km^2 formed primarily by sediment depositions. It constitutes about 7.5% of Nigeria's land mass with an annual rainfall total averaging from 2400-4000 mm. The area is influenced by the localized convection of the West African monsoon with less contribution from the mesoscale and synoptic system of the Sahel [9]. The rainy (wet) season over the region starts in May, following the seasonal northward movement of the Intertropical Convergence Zone (ITCZ), with its cessation in October [10,11]. It has an equatorial monsoon climate influenced by the south west monsoonal winds (maritime tropical) air mass coming from the South Atlantic Ocean. It is home to 20 million people drawn from nine states of the country namely Abia, Akwa-ibom, Bayelsa, Cross- River, Delta, Edo, Imo, Ondo and Rivers states with 40 different ethnic groups. This flood plain makes 7.5% of Nigeria's total land mass [12]. The study is

Table 1. Coordinates of the study locations, their elevations and duration of study

S/n	Locations	Lat(n)	Long(e)	Elevation(m)	Duration of study
1.	CALABAR	4.976	8.347	47.0	1981-2012
2.	UYO	5.038	7.909	65.0	1981-2012
3.	PORTHARCOURT	4.8156	7.0498	468.0	1981-2012
4.	OWERRI	5.483	7.0176	71.0	1981-2012
5.	WARRI	5.516	5.750	6.0	1981-2012
6.	AKURE	7.247	5.301	335.0	1981-2012

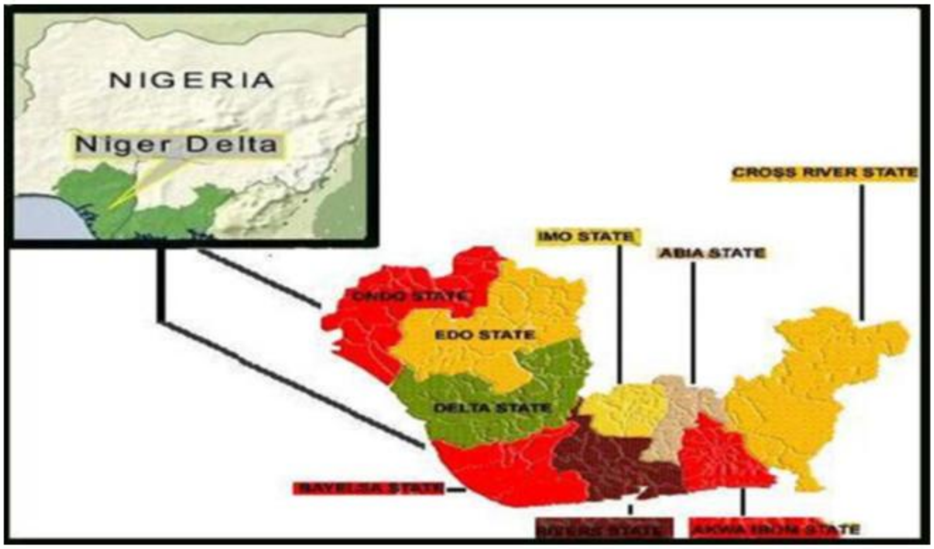

Fig. 1. Map of Nigeria showing the Niger Delta region (5.05E-7.17E and latitude 4.15 N – 7.17 N) shaded with colors

restricted to six states in the Niger Delta namely Calabar, Uyo, Port Harcourt, Owerri, Warri and Akure because there are no available data in the remaining stations Yenegoa, Umuahia and Asaba as shown in Table 1.

2. DATA ANALYSIS

A 31 years record of observational data between (1981-2012) of monthly mean horizontal visibility for some coastal weather stations in the Niger Delta Region Nigeria, Calabar (8.32E, 4.95N), Uyo (7.91E, 5.03N), Port Harcourt (7.00E, 4.75N), Owerri (7.03E, 5.48N),Warri (5.75E, 5.52N), and Akure (5.19E, 7.25N), were obtained from Nigerian Meteorological Agency Abuja (NIMET) which is the agency responsible for collecting and archiving meteorological data in Nigeria and reanalysis data for relative humidity and wind direction for the period (1981-2012) from the National Centre for Environmental Prediction (NCEP) and its available online at http://www.ncep.noaa.gov which were also extracted using Grid Analysis Display system (Grads) prepared on a resolution of 2.5° by 2.5° global grid (approximately 180 km) . However statistical trend analysis has been followed.

2.1 Anomaly

In a bid to compare the capability of each of the dataset in spatial scales, the monthly visibility anomalies of the datasets were computed from the horizontal meteorological means using the following equation.

$$X' = X - \overline{X}$$

Where,

x = the monthly visibility data from each of the datasets and

$\overline{X}$ = the corresponding horizontal climatological mean for that month.

2.2 Normalization

The monthly horizontal visibility, Relative humidity and Wind direction anomalies were normalized with the aim of putting the datasets on the same scale for comparison as well as to eliminate the influence of location and spread in the various datasets. This is achieved by the following equation.

$$z = \frac{X' - \overline{X}'}{S_{X'}}$$

Where,

X' = the monthly horizontal visibility, relative humidity and wind direction anomaly of each dataset,

$\overline{X}'$ = the mean of the total monthly horizontal visibility, relative humidity and wind direction anomaly over the period and

S = the corresponding standard deviation from x′.

3. RESULTS AND DISCUSSION

3.1 Relative Humidity Values and Seasonal Trends in the Niger Delta Region of Nigeria

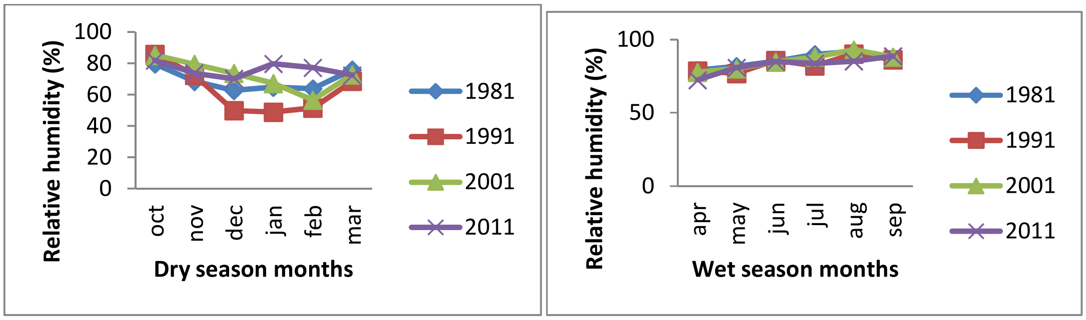

Fig. 2(a). Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Calabar

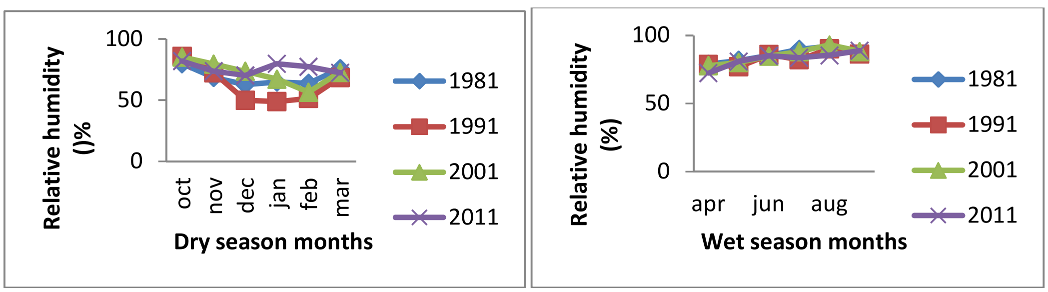

Fig. 2(b). Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Uyo

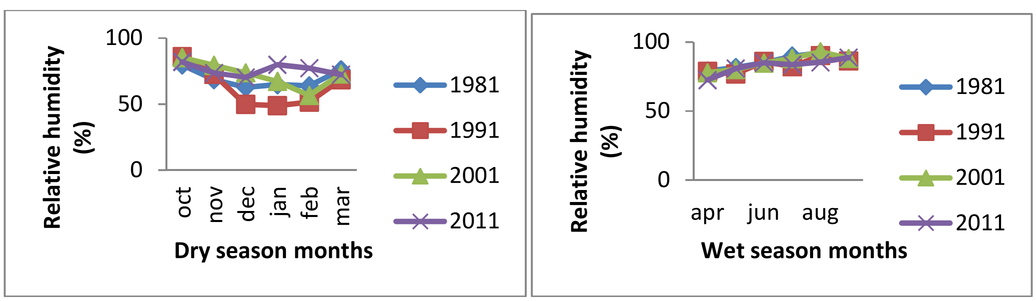

Fig. 2(c). Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Port Harcourt

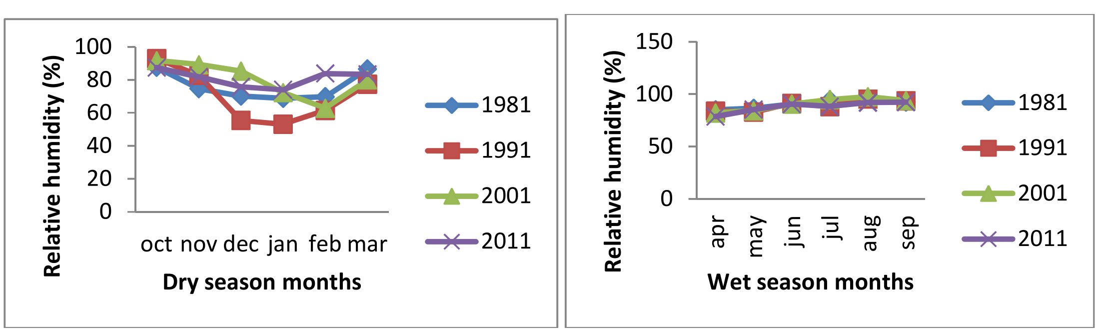

Fig. 2(d). Seasonal trends for (i) dry season months and (ii) wet season months for relative humidity in Owerri

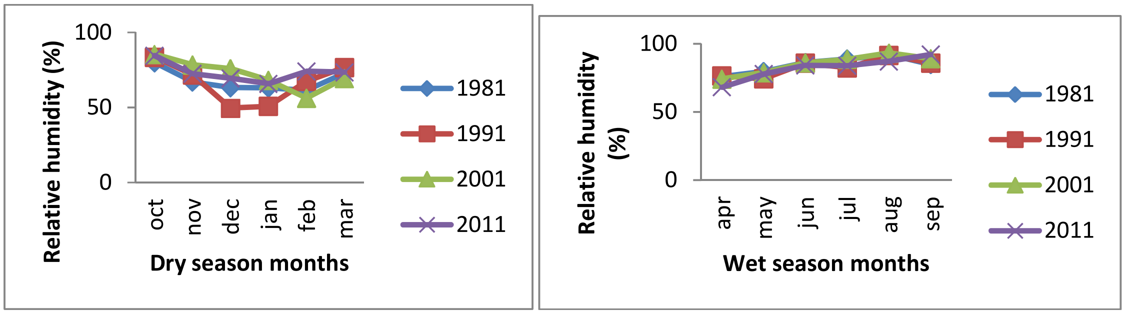

Fig. 2(e). Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Warri

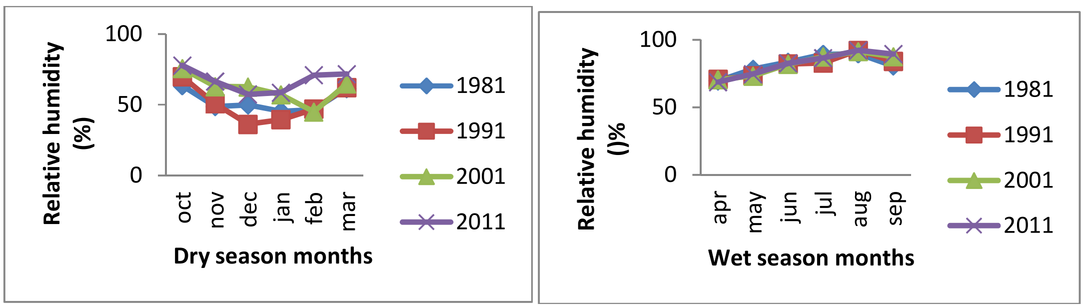

Fig. 2(f). Seasonal trends for (i) dry season months and (ii) wet season months for Relative humidity in Akure

3.2 Wind Direction Values and Seasonal Trends in the Niger Delta Region of Nigeria

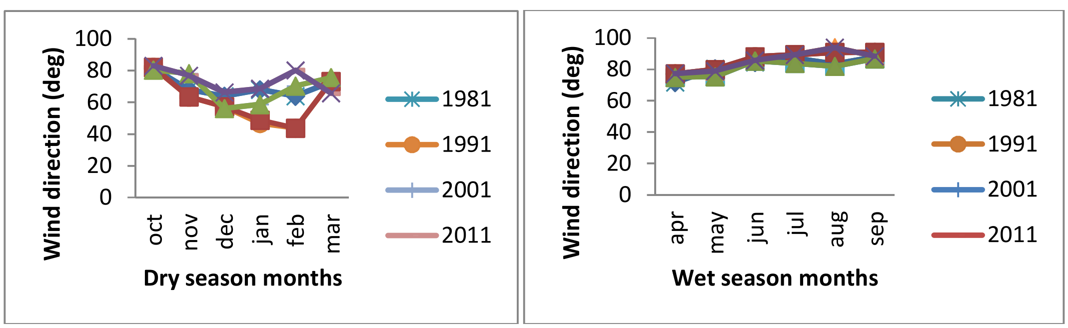

Fig. 3(a). Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Calabar

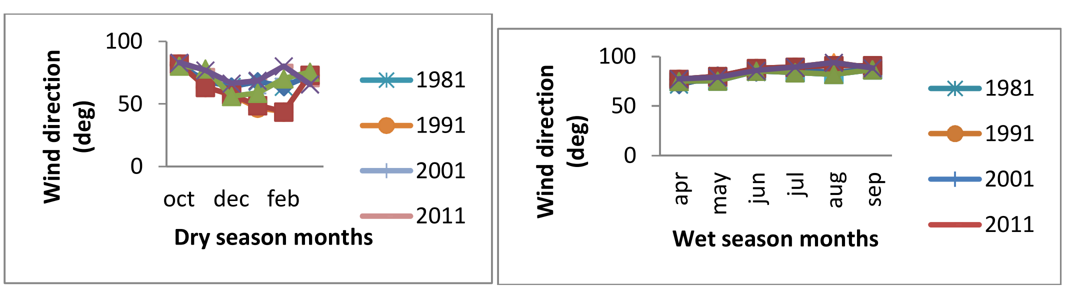

Fig. 3(b). Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Uyo

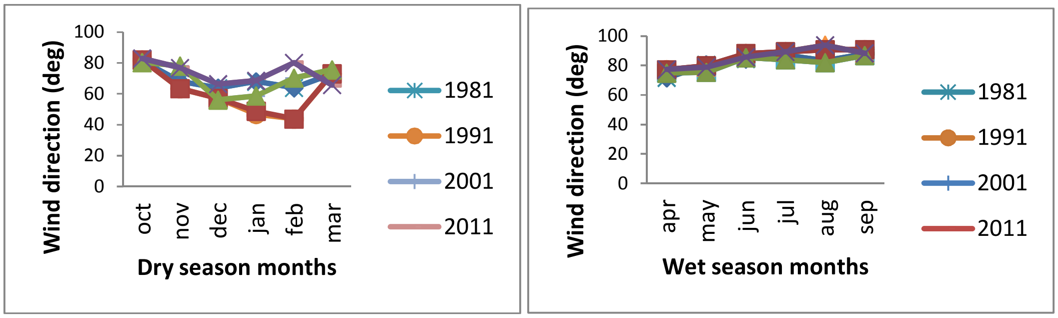

Fig. 3(c). Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Port Harcourt

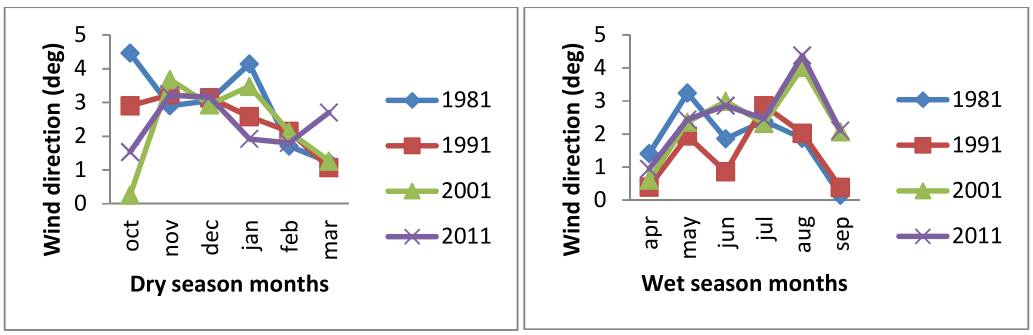

Fig. 3(d). Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Owerri

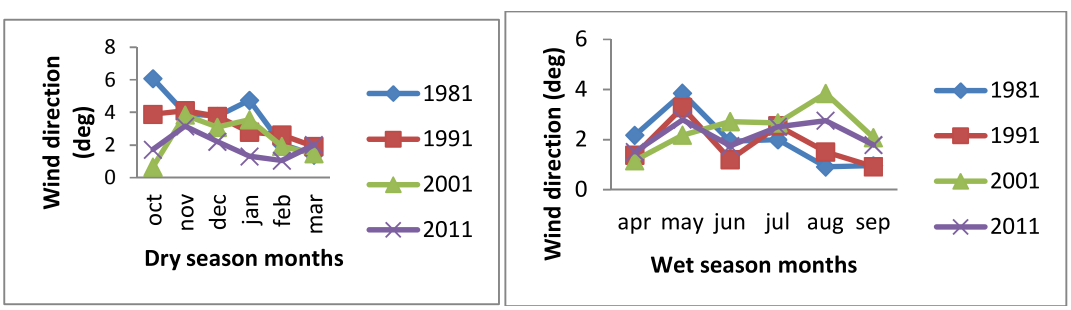

Fig. 3(e). Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Warri

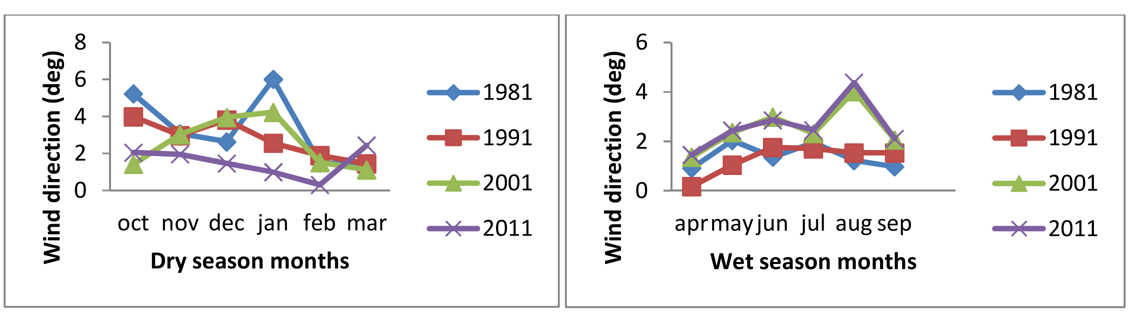

Fig. 3(f). Seasonal trends for (i) dry season months and (ii) wet season months for Wind direction in Akure

3.3 Visibility Values and Seasonal Trends in the Niger Delta Region of Nigeria

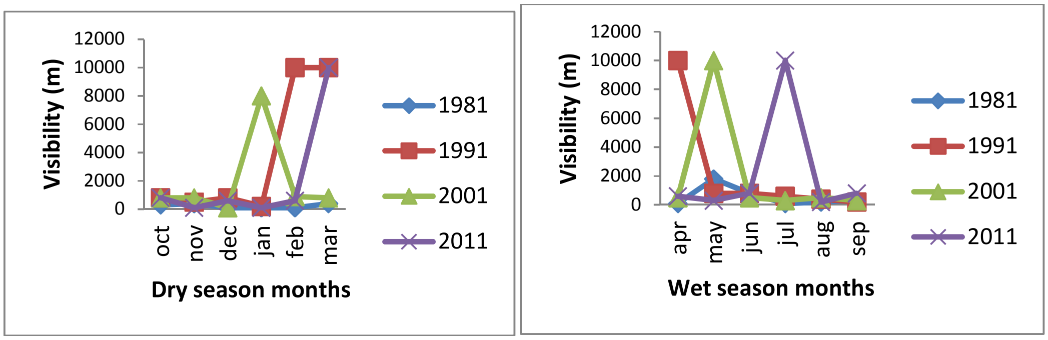

Fig. 4(a). Seasonal trends for (i) dry season months and (ii) wet season months for Visibility in Calabar

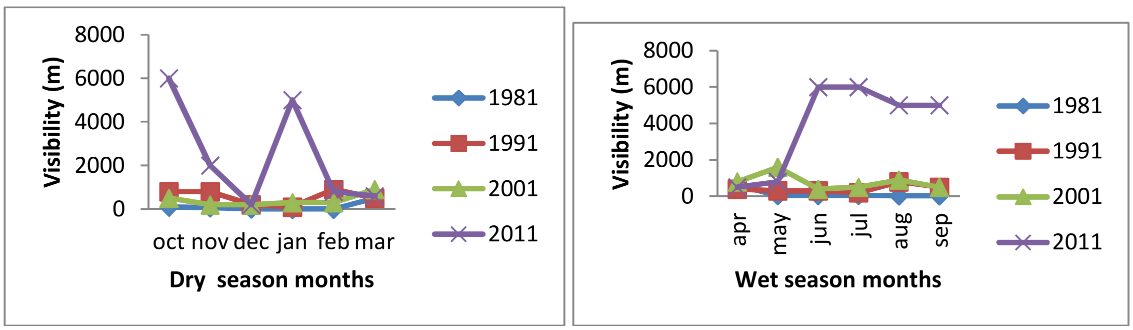

Fig. 4(b). Seasonal trends for (i) dry season months and (ii) wet season months for Visibility in Uyo

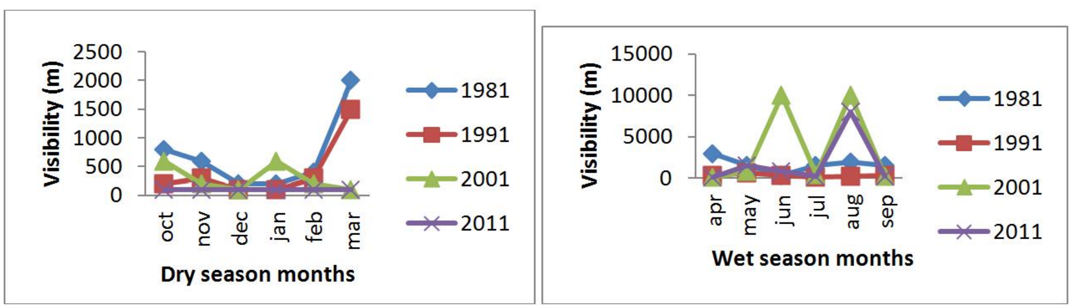

Fig. 4(c). Seasonal trends for (i) dry season months and (ii) wet season months for Visibility in PhC

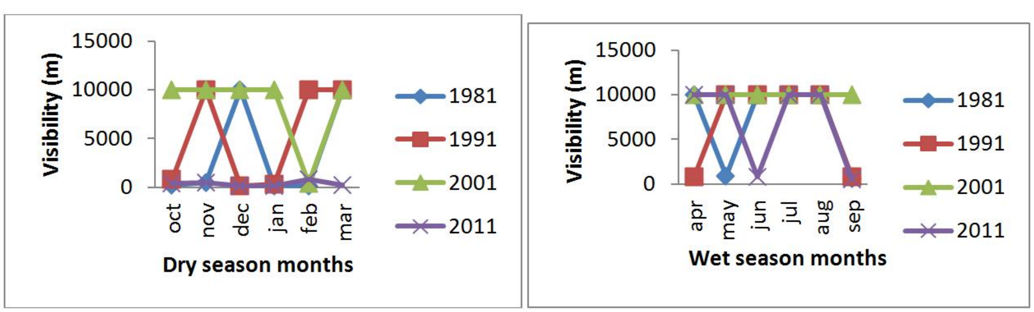

Fig. 4(d). Seasonal trends for (i) dry season months and (ii) wet season months for Visibility in Owerri

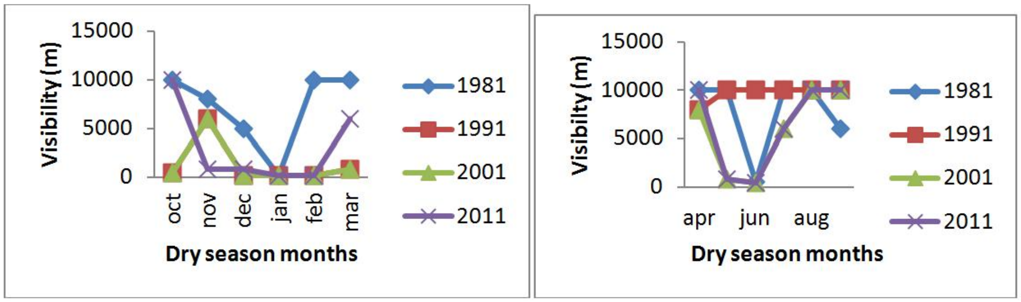

Fig. 4(e). Seasonal trends for (i) dry season months and (ii) wet season months for Visibility in Warri

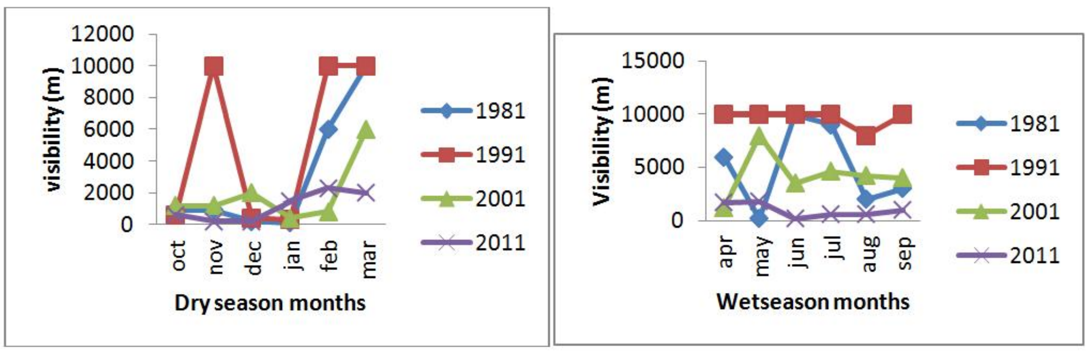

Fig. 4(f). Seasonal trends for (i) dry season months and (ii) wet season months for Visibility in Akure

Seasons in Nigeria is divided into dry (hot) and wet (rainy) seasons. Relative humidity is classified as follows for the purpose of the discussion in this work, namely below 70% is low to very low relative humidity ie the atmospheric water content (hygroscopic potential) is very low while above 70% is high relative humidity where the atmospheric water content (hygroscopic potential) is high to very high. Using this criteria, the performance of relative humidity for the months (season), years and cities are as presented.

3.3.1 Relative humidity trends in dry season months (Oct, Nov, Dec, Jan, Feb, March)

Relative humidity values are generally low in dry season months of Nov, Dec, Jan, Feb and March. December and February are the months with highest cases of low RH for all the years studied. Of the dry season months October has the fewest cases of low RH for all the stations and for all the years considered. This result shows that dry season months generally has less moisture in the atmosphere as a result of the high evaporation and transport of water taking place on the earths surface to higher levels in the atmosphere.

3.3.2 Relative humidity trends in wet season months (April, May, June, July, Aug, Sept)

The results in Table 2 also shows wide spread of high relative humidity throughout all the wet months for all the years and cities under consideration. In addition the result shows that most cities and years in the wet season months recorded high relative humidity as well. This is indicative of the fact that relative humidity values in the Niger Delta Region are very high due to the high moisture in the atmosphere as a result of its proximity to the Atlantic Ocean and the presence of rivers and creeks in the area.

Relative humidity is usually low from January through March, then it starts to improve from April through to September and even to October before dropping again. The months of high Relative humidity are those months when the region is under the influence of West African Moonsoon as the inter-tropical convergence zone (ITCZ) moves up into the land areas of the region while the month of low relative humidity coincides with those months when the region is under the influence of the dry cold North-East Trade Wind from the sahel which dries the atmosphere which generally lowers the water content of the atmosphere in the Niger Delta region.

3.4 Relative Humidity Trends for the Cities in the Niger Delta

The analysis spread shows that Calabar, Uyo, PHC and Owerri have high relative humidity as tallied from the number of occurrences in the locations in the years under study from 1981-2012 in the relative humidity data, these values indicate that these cities are highly humid for most of the months as shown in Table 2. On the other hand, Warri and Akure have more low R-H values indicating that these cities have drier atmosphere for the years under consideration. The highest R-H values observed for Owerri, even higher than those in the cities of Cal, Uyo and PHC seem to be a misnomer to the expected values of R-H in Owerri for the years under consideration. Nevertheless, this seems to tally with the high visibility values also observed for Owerri when it is expected to have degraded visibility level.

Table 2. Relative humidity analysis spread for the cities in the Niger Delta region

City	Low RH values (%)	High RH values (%)
Cal	11	37
Uyo	11	37
PHC	10	37
Owerri	10	38
Warrri	14	34
Akure	21	27

4. SEASONALITY OF WIND DIRECTION VALUES IN THE NIGER DELTA REGION

Wind direction values were found not to be uniform throughout the region. Three eastward cities namely Calabar, Uyo and Port Harcourt have very high wind direction values of mostly 40 and above. For these cities, the wind values have been classified as follows for the purpose of discussion in this work. Wind direction values of between 70 and 40 are considered low values while values above 70 are considered high wind direction values as also tallied from the number of occurrences in the locations in the wind direction data for the years under study 1981-2012.

On the other hand, three westward cities namely Owerri, Warri and Akure that lie more to the west of the region have low wind direction values ranging from about 0 to 7 as tallied from the wind direction data for the locations under study 1981-2012. For these cities values of between 1 and 3 are considered low values of wind direction whereas values between 3 to 7 are considered high wind direction values. Using these criteria, the performance of wind direction is as presented respectively.

4.1 Wind Direction Trends for the Cities under Consideration

From the spread analysis above, it is obvious that all the Eastern cities of the region have uniform spread of high and low values of wind direction spread. Whereas the western cities (including Owerri) do not have uniform spread. Owerri has higher values of wind values. This is followed by Akure and then Warri (Table 3). The spread does not also follow westerly trend as the values for Akure are higher than those for Warri.

Table 3. Wind direction spread analysis for the Eastern and Western cities

City	Eastern cities		City	Western cities	
	Low values (deg)	High values		Low values (deg)	High values
Calabar	13	35	Owerri	11	37
Uyo	13	35	Warri	14	34
Port Harcourt	13	35	Akure	12	36

5. CONCLUSION

The seasonal trends of Relative humidity and Wind direction as shown have their peaks in the dry season months, October to March, the implication is that most of these dry season months are when most of the region is under the influence of the North Easterly winds which is cold, dry and brings dust from the desert especially cities which are in the heart of the hydrocarbon industry like Calabar, Uyo and Port Harcourt. Visibility degradation is not only influenced by concentrated air pollutants but also by complicated meteorological factors such as relative humidity, wind speed, atmospheric pressure, this is evident hence the annual visibility variability indexes from (NIMET) shows significant correlation with the (NCEP) datasets for relative humidity at $r = 0.1334$ and Wind direction at $r = 0.1210$ respectively at 90% confidence level from t-test [13]. This study concluded that the relationship of the atmospheric visibility and meteorological factors are closely related. This comparison does not provide all the uncertainties that would be found from each of the dataset over the Niger Delta but it's a measure of the expected minimum uncertainty in the dataset which should guide scientists and researchers carrying out studies on regions of this scale.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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